RESEARCH NOTES

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Caltrans GPS Monitoring System Tracks Deformations During Full-Scale Earthquake Tests

RESULTS: ***Caltrans research has demonstrated that movements of landslides and bridges could effectively be monitored remotely using Real-Time Kinematic Global Positioning System (RTK-GPS) and wireless technologies. Extensive tests of RTK-GPS verified centimeter-level accuracies, effective for tracking a wide range of dynamic motions. The deployment of a system for a full-scale earthquake test in Japan demonstrated the flexibility and stability of a pilot system, while providing an otherwise unattainable data set for earthquake researchers.***

Why We Pursued This Research

Advances in GPS technologies have made ground surface displacement measurements under static as well as dynamic conditions easier to obtain with increased accuracy and reduced costs. Limitations in conventional displacement sensors have made large-scale deformation monitoring applications challenging, such as those employed in the study of landslides and bridges. Geotechnical and structural practice increasingly demand measurements of soil mass and structure deformations (for example, landslides, lateral spreading from earthquakes, long-period bridge response during earthquakes), so the benefits of GPS in complementing more conventional instrumentation technologies appear promising, particularly in remote monitoring applications.

What We Did

An in-house research project was initiated a few years ago to evaluate the feasibility of studying geotechnical and structural phenomena with a GPS-based instrumentation package utilizing emerging high precision RTK-GPS and wireless communications technologies. The project involved systematic validation testing, systems integration, prototype development, and, finally, a test deployment of the system in a full-scale earthquake experiment at a port facility in northern Japan in late 2001.

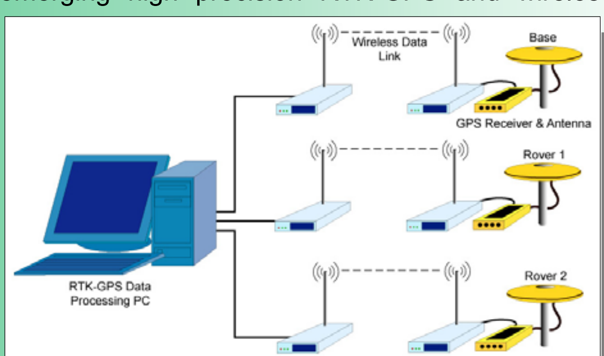

Figure 1 – System Architecture

The system was developed primarily for the remote monitoring of landslide and bridge movements. GPS field units transmit raw data wirelessly to an office PC for processing and data visualization (Fig.1). The system provides a real-time data stream of up to 20 data points per second with centimeter accuracy.

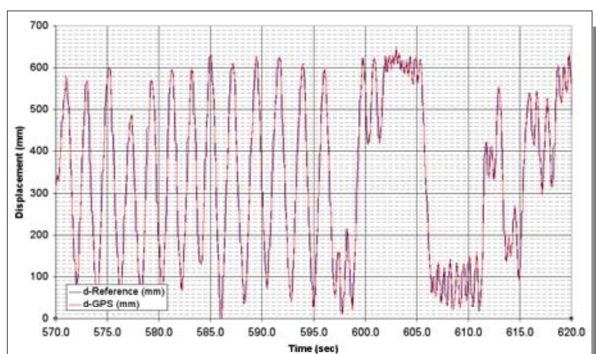

Figure 2 – Bench test results validate RTK-GPS methods

To quantify "real-world" performance and demonstrate the viability of RTK-GPS as a displacement measurement tool, a series of bench tests were performed, simulating the range of magnitudes, rates, and frequencies of displacements typically encountered in landslide and bridge monitoring applications. Validation test results clearly demonstrated the accuracy of RTK-GPS under static and dynamic conditions (Fig.2).

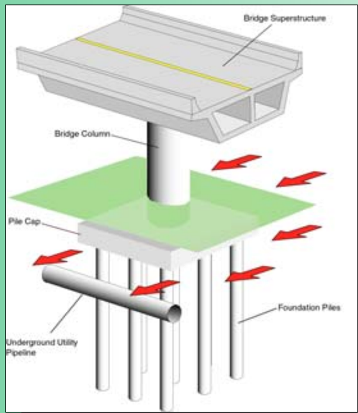

Figure 3 – Earthquake loads (lateral spread) on bridge

Two full-scale earthquake tests conducted in Japan in late 2001 provided a unique opportunity to deploy the Caltrans RTK-GPS system in a controlled test environment. The focus of the study was to collect data on the response of civil structures, such as bridge foundations, and utility pipelines during severe loading induced by earthquakes (Fig.3). Accurate measurements of ground deformations (from liquefaction and lateral spread) during the generated seismic events were a critical research component and were impossible to obtain by conventional instrumentation techniques.

The Caltrans team deployed a total of twelve GPS units at the site, an area approximately 50 by 100 meters, bordered on one end by a large waterway with the soil held back by a sea wall. Explosive charges, placed in a grid pattern across the site, were used to generate the earthquake loads.

Figure 4 – Blasting underway at Japan test site

Despite challenging environmental conditions, including record-setting 100 kilometer per hour winds and heavy snowfall during the second test, the GPS monitoring package performed well. The tests demonstrated the versatility and robustness of the GPS monitoring package under severe inclement weather and turbulent environments.

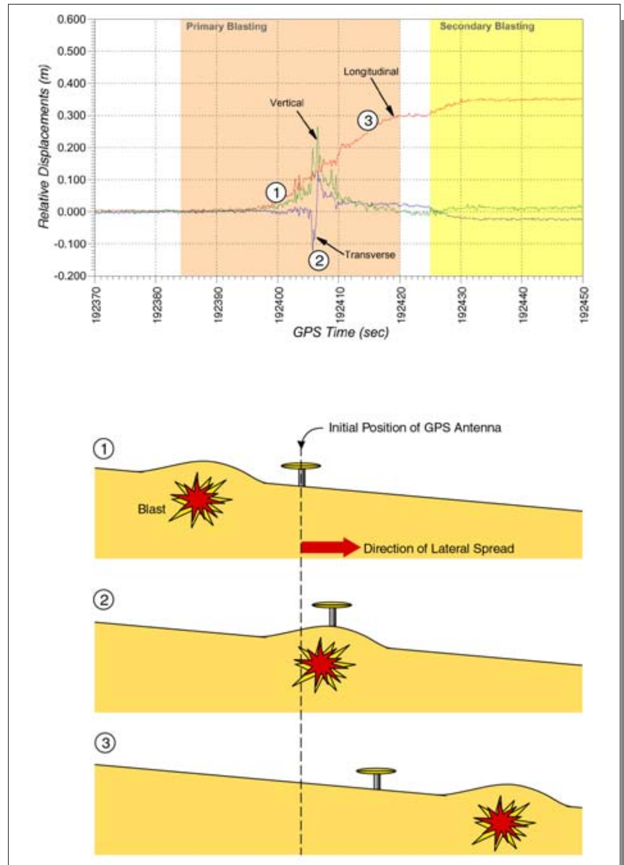

Figure 5 – GPS data during blasting

The Researchers Recommend

Test deployments and validation testing have shown that networked RTK-GPS is a good tool for displacement measurements, and is recommended for Caltrans' instrumentation practice. Additional research into long-term performance and system maintenance issues need to be investigated in a third phase of the project. GPS technologies and products continue to improve and the Department should continue to explore the potential for other applications. A few commercially available solutions have also come to market since the project began and should be evaluated for more routine deployment.

For Additional Information

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